Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
Unlicensed Use of the 6 GHz Band	)	ET Docket No. 18-295
Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz	)	GN Docket No. 17-183

REPLY COMMENTS OF BROADCOM INC.

Christopher Szymanski
Director, Product Marketing and Government Affairs

Vinko Erceg
Fellow, Systems Engineering

Thomas Derham
Principal Scientist, Systems Engineering

BROADCOM INC.
15191 Alton Parkway
Irvine, CA 92618

March 18, 2019

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INTRODUCTION AND SUMMARY

As the Federal Communications Commission ("FCC" or "Commission") has recognized, Americans' increasing demand for Wi-Fi has created an urgent need for more unlicensed spectrum.[1] Broadcom agrees with the Commission that the 6 GHz band presents an important opportunity to meet that demand. Commenters responding to the FCC's Notice of Proposed Rulemaking ("NPRM") demonstrate that the Commission can open the band to unlicensed technologies while protecting incumbent operations. Broadcom joins the reply comments being filed today by Apple Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., Microsoft Corporation, Qualcomm Incorporated, and Ruckus Networks, and we file these separate reply comments to provide responses to engineering issues raised on the record and to urge the Commission to reject calls to impose technical rules that create unnecessary layers of regulation or that favor particular technologies.

First, commenters demonstrate that the Commission's determination that Radio Local Access Networks ("RLANs") will protect Fixed Service ("FS") operations in the 6 GHz band is correct. FS interests now focus on unlikely corner-case interference scenarios in arguing for additional regulation. In the vast majority of situations, however, RLANs will not be positioned to raise any harmful interference concerns at all. And an analysis of FS system operations shows that if the unrealistic combination of improbable events conjured by FS interests somehow were to occur, it would not degrade FS operations in the real world. Properly engineered FS paths have significantly more signal-to-noise ratio ("SNR") than necessary to achieve their mission. Interference analysis that considers excess

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[1] *Unlicensed Use of the 6 GHz Band; Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, Notice of Proposed Rulemaking, FCC 18-147, ET Docket No. 18-295, GN Docket No. 17-183, ¶ 4 (rel. Oct. 24, 2018) ("NPRM").

margin designed into properly engineered FS paths confirms that even an RLAN operating (1) in the main beam of such a path, (2) on the exact floor of a high building that puts it at the same z-coordinate, and (3) where there is no clutter between the RLAN and the FS receiver still would not degrade an FS path in practice.

Second, the Commission should reject calls to impose unnecessary and complex operational regulations in U-NII-5 that a small number of Intelligent Transportation System ("ITS") commenters recommend. These restrictions would cripple RLAN operations in those frequencies. Instead, the Commission should continue to apply its existing rules that protect ITS from out-of-band emissions ("OOBE") from U-NII-3. Proponents of cellular vehicle-to-everything ("C-V2X"), an ITS service that is not currently authorized to operate in the adjacent 5.9 GHz band, argue that extraordinary measures should be taken to protect their as-yet unauthorized future operations. But these parties have not provided any reliable technical support for their proposal—or even the basic information required to evaluate their claims. The Commission has no reason to depart from the OOBE rules it has already adopted in U-NII-3 to protect ITS.

Third, one company asks the Commission to reserve the entire U-NII-7 band for unlicensed technologies that use "synchronized operations" and to block all others. This is nothing more than a request to favor certain unlicensed technologies. That would undermine the value of the band, violate the FCC's technology-neutral approach to spectrum allocation, and deny access to the band for the majority of potential uses. Instead, the Commission should leave matters related to technical implementation to standards bodies, as it has always done.

Based on the robust record it has developed, the Commission should now adopt the NPRM's proposals, with the important modifications described in the RLAN Group

Comments.[2] With those rules in place, the Commission will support the investment and innovation needed to quickly expand wireless services in the 6 GHz band.

I. The record demonstrates that RLANs can co-exist with FS paths without causing harmful interference.

Comments from a wide range of parties show that standard-power, indoor low-power, and very-low-power RLAN operations will deliver enormous benefits to the country without causing harmful interference to FS operations.[3] Broadcom supports the

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[2] Comments of Apple Inc., Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., Microsoft Corporation, Qualcomm Incorporated, and Ruckus Networks, an Arris Company at 3, ET Docket No. 18-295, GN Docket No. 17-183 (filed Feb. 15, 2019) ("RLAN Group Comments"). Unless otherwise noted, all comments cited were filed February 15, 2019 in ET Docket No. 18-295 and GN Docket No. 17-183.

[3] Numerous commenters support authorizing indoor low-power operations throughout the 6 GHz band. Comments of Apple Inc. at 3 ("Apple Comments"); Comments of the Boeing Company at 6–7; Comments of Broadcom Inc. at 5–16 ("Broadcom Comments"); Comments of Cambium Networks, Ltd. at 2; Comments of Charter Communications, Inc. at 3; Comments of Cisco Systems, Inc. at 10–13; Comments of the Computing Technology Industry Association (CompTIA) at 2; Comments of Facebook, Inc. at 3–4 ("Facebook Comments"); Comments of GE Healthcare at 7–8; Comments of Hewlett Packard Enterprise at 7–17 ("HPE Comments"); Comments of HP Inc. at 3–4 (filed Feb. 13, 2019); Comments of Microsoft Corporation at 5–11; Comments of NCTA – The Internet & Television Association at 15–16; NETGEAR Comments at 2–3 (filed Feb. 13, 2019); Comments of Open Technology Institute at New America, American Library Association, Consumer Federation of America, COSN—Consortium for School Networking, Public Knowledge, Access Humboldt at 17–20; Comments of Qualcomm Incorporated at 9–10 ("Qualcomm Comments"); Comments of Quantenna Communications, Inc. at 3–4 (filed Feb. 14, 2019); Comments of Wi-Fi Alliance at 10–17; Comments of the Wireless Internet Service Providers Association at 27–28. Many commenters also support opening the band to very-low-power portable unlicensed operations. Apple Comments at 2–3, 7–9; Broadcom Comments at 27–31; Facebook Comments at 5–6; HPE Comments at 7, 16–17. Additionally, many commenters recognize that the Commission's AFC proposal will protect licensees, clearing the way for outdoor, standard-power RLAN operations. *See* Reply Comments of Apple Inc., Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., Microsoft Corporation, Qualcomm Incorporated, and Ruckus Networks, an Arris Company at 4–8, ET Docket No. 18-295, GN Docket No. 17-183 (filed Mar. 18, 2019).

NPRM's proposed Automated Frequency Coordination ("AFC") system, which is designed to protect incumbents from interference from standard-power unlicensed operations.[4] Broadcom has also demonstrated that AFC control is not needed for indoor low-power operations or for very-low-power operations because harmful interference from these devices to FS operations is extremely unlikely. Nonetheless, FS operators continue to focus on one scenario: an indoor device operating in a building, with line-of-sight operations, and located in the main beam of an FS receiver. But this situation is extremely uncommon. And even in that scenario, numerous factors, including network geometry, building entry loss, antenna direction and polarization, and the unlikelihood of co-channel operations, combine to offer FS operations multiple layers of protection.[5] Accordingly, the record demonstrates in detail that interference from 6 GHz RLANs to FS paths in real-world scenarios—including potentially problematic cases like RLANs operating near open windows[6]—remains below -6 dB interference-to-noise ("I/N").[7]

Supplementing I/N Analysis with a Supplemental Margin Analysis. The evidence already in the record is more than enough to support a Commission decision to permit unlicensed operations under the rules Broadcom supports. To supplement that evidence, Broadcom conducted a margin analysis that confirms that sharing is safe and

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4 *See* NPRM ¶ 25.

5 Broadcom Comments at 8–17, 28–35.

6 *Id.* at 19.

7 A wide range of parties agreed that an interference level in the -6 dB I/N range represents a conservative assurance that harmful interference will not occur. *See, e.g.*, Comments of Comsearch at 21 ("Comsearch Comments"); Comments of the Fixed Wireless Communications Coalition at 22 ("FWCC Comments"). Hewlett Packard Enterprise Company has demonstrated that use of a 0 dB I/N threshold is also warranted. HPE Comments at 27–28.

practical and that FS paths have more than enough margin to achieve their design requirements, even in the extremely unlikely event that a 6 GHz RLAN hits the "interference lottery."[8] While a margin analysis is not necessary to demonstrate that the FCC can permit RLAN operations in the 6 GHz band without harming incumbent operations—the I/N analysis documented in the record makes that clear—examining the typical margin for FS operations in the 6 GHz band reinforces that conclusion.

FS paths are typically designed for extremely high levels of reliability—as low as 99.7 percent availability to individual paths in the utility industry[9] and up to 99.999 or even 99.9999 percent for some of the other fixed services. To achieve this level of reliability, FS path designers include mitigations that account for the path-signal fades and other incidental degradations that all microwave signals are vulnerable to—even in the absence of any other nearby operations. In fact, those sources of degradation dwarf any possible interference effects that are likely to be caused by RLANs. Thus, all FS paths have margins to ensure that, even if the signal is degraded, the path will still meet its reliability goal for the minimum desired modulation on that radio's path. While engineers typically design individual paths and overall networks to meet specified error performance and availability objectives, from a practical standpoint, paths in a network are often implemented with margins higher than necessary to achieve these design objectives.

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8 HPE Comments at 13.

9 Comments of the Utilities Technology Council, The Edison Electric Institute, The American Public Power Association, The National Rural Electric Cooperative Association, The American Petroleum Institute and The American Water Works Association Attach. at 15.

Understanding the margin built into 6 GHz FS systems is essential to any policy decision involving the public interest because, as explained in the Telecommunications Industry Association's *Interference Criteria for Microwave Systems*, when FS systems have excess margin, interference protection criteria "may be relaxed dB for dB."[10] In other words, where margin is available above target fade margin levels, the baseline I/N interference protection criteria will be more restrictive than necessary to maintain the FS path's reliable performance. 6 GHz FS paths typically have target fade margins of between 25 and 40 dB.[11] A specific path's target fade margin is a factor of many variables, such as required availability, interference protection criteria, path distance, climate factor, K-factor, and the extent to which the geographic area is subject to multipath fade. Analyses of the FS links considered in the RKF report (those that were registered in the FCC's Universal Licensing System ("ULS") in March 2017) and of those that have been registered more recently demonstrates that typical FS systems have margins that far exceed the required levels, which would allow interference above the -6 dB I/N threshold without causing *harmful* interference by actually degrading FS link reliability.

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[10] National Telecommunications and Information Administration, NTIA Report 05-432, Interference Protection Criteria, Phase 1 – Compilation from Existing Sources 4–8 (2005), https://www.ntia.doc.gov/files/ntia/publications/ipc_phase_1_report.pdf (citing TIA TSB 10-F).

[11] According to FWCC, "fade margins are typically in the range of 25-40 dB." FWCC Comments at 16. As the RKF analysis summarized below demonstrates, average margins over the entire installed base appear to be significantly higher. The lower end of FWCC's range likely reflects FS links with multiple modulation capabilities that operate with lower margins in their higher modulation modes because they can reliably fall back to a lower modulation (and higher fade margin) if necessary. *See also* HPE Comments at 15; Comsearch Comments at 21 ("Our data on 6 GHz digital receiver fade margins from 2018 showed a mean of 38 dB with 90% in the range 30 to 46 dB.").

RKF Margin Analysis. The report RKF prepared earlier in this proceeding calculated FS link margin for 90,486 of the 91,187 FS links registered in ULS at that time.[12] As explained in the RKF report, link margin can be derived from equivalent isotropically radiated power ("EIRP"), path loss, FS receiver gain, Boltzmann's constant, system temperature, signal bandwidth, and required SNR. Because the required SNR is not included in ULS, RKF derived it from modulation data in ULS and the efficiency vs. SNR curve in Figure 1 below. Where that data was not available, RKF included the link and assumed that a minimum of 19 dB signal-to-noise ratio was required to achieve 64 quadrature amplitude modulation ("QAM").[13] Using these assumptions, RKF concluded that the median margin of these links was 50.8 dB, well above the 25 to 40 dB design target described by the Fixed Wireless Communications Coalition ("FWCC").

Analysis of FS Links Registered After March 2017. To supplement the RKF analysis, we reviewed the new Part 101 FS paths operating in the U-NII-5, 7, and 8 bands from March 21, 2017 to January 23, 2019, a total of 5414 new paths.[14] Consistent with the analysis in our comments,[15] we assumed a 5 dB noise figure and 3 dB of feeder and system

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[12] To determine average fade margins, RKF excluded a small percentage of links with very low fade margins or with very high fade margins, which were presumed to reflect database errors. RKF Engineering Services, LLC, Frequency Sharing for Radio Local Area Networks in the 6 GHz Band 50 (2018), https://ecfsapi.fcc.gov/file/101261169015803/6%20GHz%20Ex%20Parte%20(Bureaus).pdf.

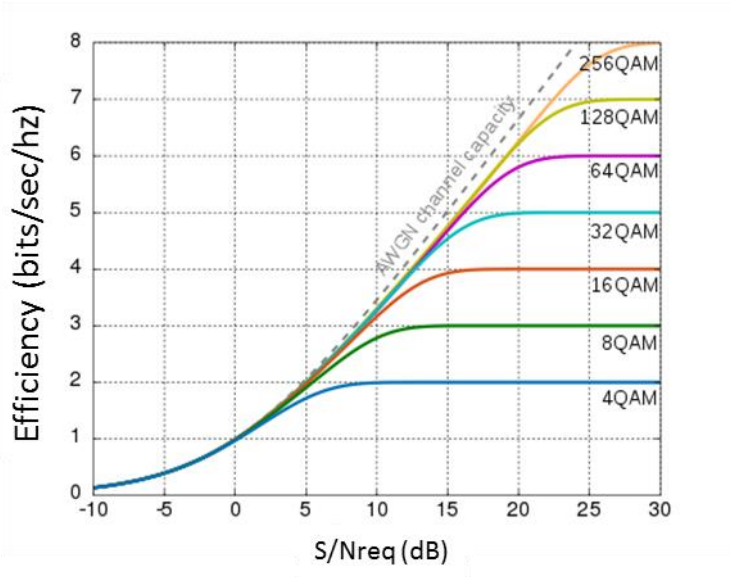
[13] According to ITU-R F.758, 64 QAM should be the modulation scheme studied. Part 101 requires 4.4 bits/s/hz 99.9 percent of the time.

[14] To identify new paths, we chose call signs that were listed in ULS when conducted this analysis but were not listed as of March 21, 2017. In order to simplify the analysis, we removed 109 paths that did not employ QAM modulation resulting in a total of 5523 paths that were analyzed.

[15] Broadcom Comments at 17.

loss, which led to a margin 4 dB lower across the board than what RKF assumed. We used the same efficiency (bits/s/Hz) vs. SNR curve used by RKF, reproduced below, which assumes theoretical capacity.[16] We note that many potential gains (including any form of frequency, space, or polarization diversity) were not included in the RKF study or these reply comments.

Figure 1: Efficiency v. S/R Requirement



We then looked at those paths that had multiple modulations listed and those that only had a single modulation listed and analyzed both sets of data separately.

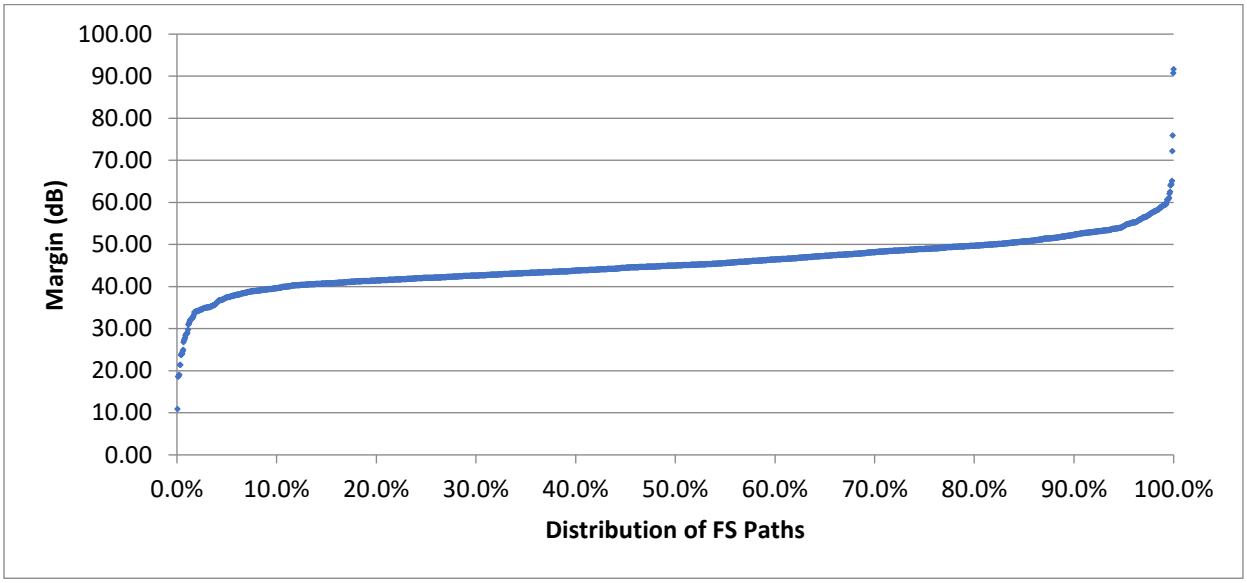
Single-Modulation FS Paths. In our dataset of new links, there were 2,110 paths that only listed a single modulation—presumably meaning that they cannot fall back to a lower modulation when experiencing high levels of fade. The declarations of Fred Goldstein

[16] We note that this is a theoretical curve. Real-world systems may be less efficient. Modern equipment uses capacity-achieving codes such as forward error corrections ("FEC") like LDPC (low-density parity check) and other receiver techniques to approach the theoretical capacity. We note that less efficient implementations will require a few dB higher in SNR for the targeted modulation and coding rate.

and Ira Wiesenfeld noted that adaptive modulation has been pervasive for many years.[17] As such, we believe that the single modulation records in ULS may reflect the design target that was coordinated through the Part 101 process but that such equipment may be capable of adapting up or down as link conditions permit. Nevertheless, for this analysis we limit ourselves to the declared modulation in ULS. Figure 2 below demonstrates that these paths have more than sufficient margin to account for even the deepest fades, as well as any rare and incidental RLAN interference. Only three percent of these single-modulation FS paths are operating with less than 35 dB of margin. Notably, the vast majority of paths are operating with above-target margins despite using relatively high modulations. Only 28 paths were listed to operate below 64 QAM, and more than 85 percent were listed as achieving 128 QAM or more. Furthermore, these paths contained a heavier distribution of shorter paths than the more comprehensive dataset that RKF analyzed, and the resulting average path distance was below 27 kilometers. Because distance is one factor in determining the amount of fade margin required for a path, it is likely that less margin was required for this dataset.

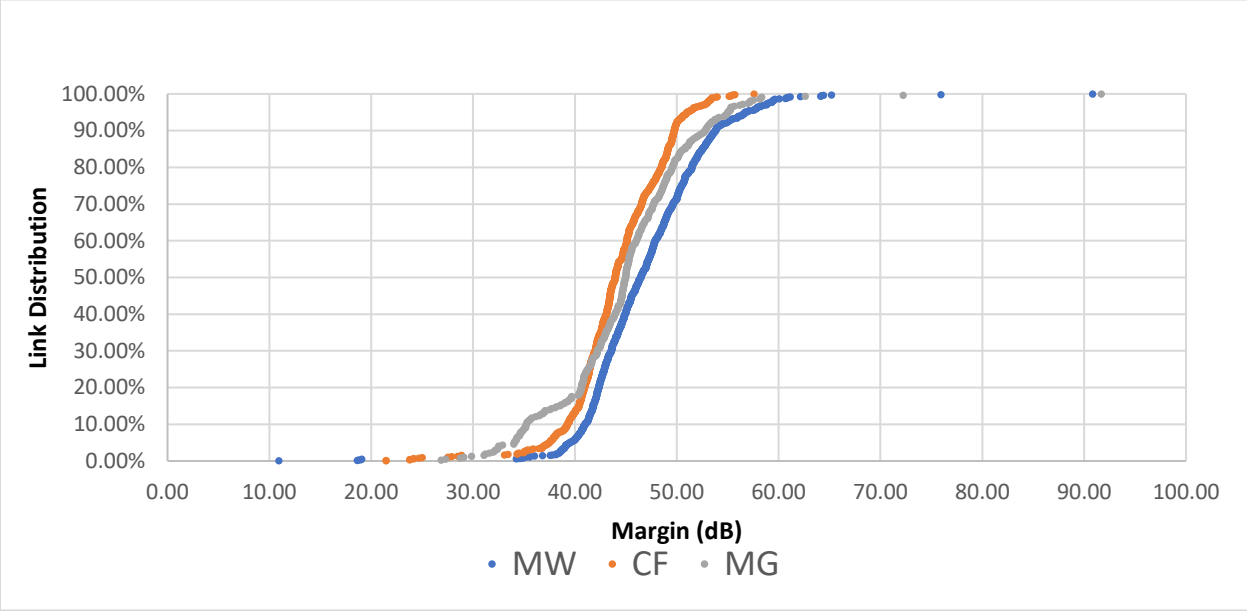
[17] RLAN Group Comments, Declaration of Fred Goldstein Regarding Fixed Service Operation ¶¶ 34–40; HPE Comments, Appendix 2: Declaration of Ira Wiesenfeld Regarding Low-Power Indoor Radio Local Area Network Devices Interfering with Fixed Station Microwave Services at 16.

Figure 2: Distribution of FS Margin (in dB)
for Paths with a Single Modulation Listed in ULS



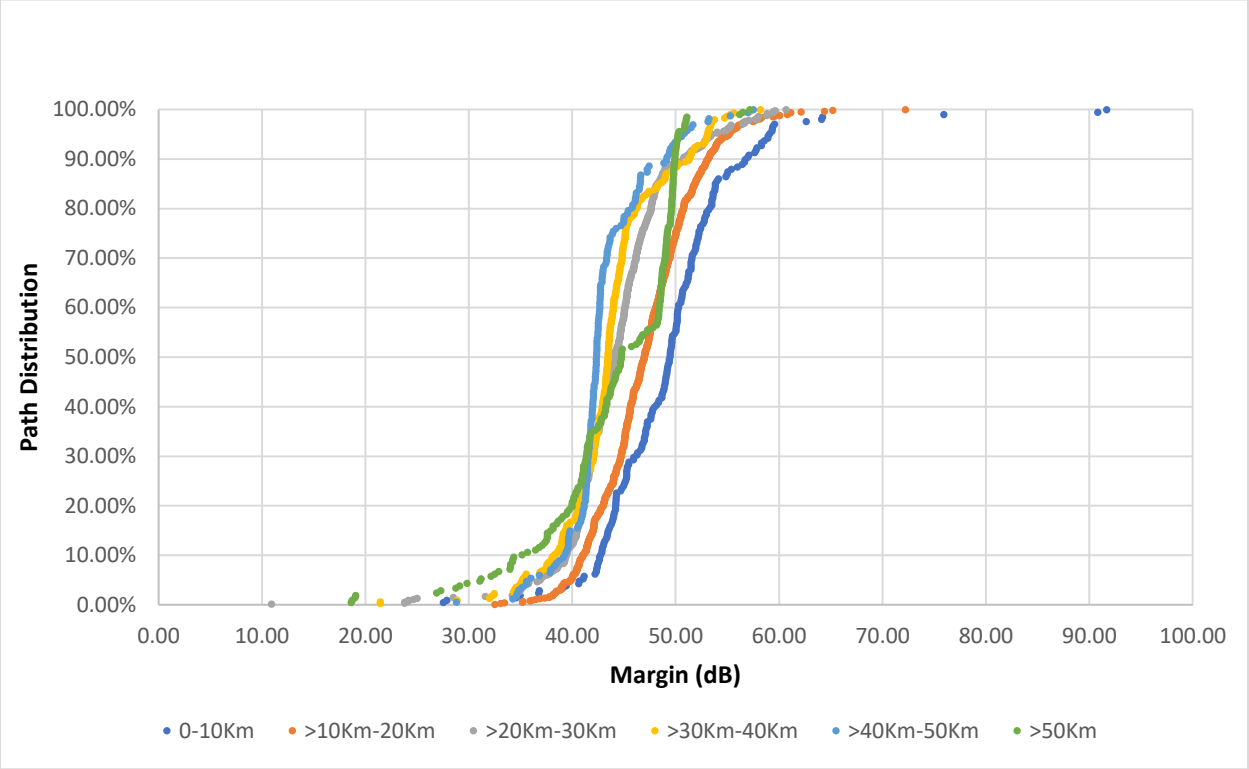
We then compared the margin for the three different types of Part 101 services: common carrier (CF), public safety (MW), and business industrial (MG) paths. The vast majority of paths of all three types operate with margins above the 25 to 40 dB range. In addition, we note that critical public safety services had on average a 2 dB higher margin than the other services as shown in Figure 3 below.

Figure 3: Distribution of FS Margin (in dB)
for Paths with a Single Modulation Listed in ULS by Radio Service



Finally, we analyzed margin by path distance, and found as expected, that shorter paths typically have much higher margins as shown in Figure 4 below.

Figure 4: Distribution of FS Margin (in dB)
for Paths with a Single Modulation Listed in ULS by Link Distance



This finding is especially critical since we have found that receivers located in urban and suburban areas, which will have a higher density of RLAN use, are typically part of shorter paths and have far more margin than the receivers for longer paths that are more typically located in rural and barren areas. Furthermore, we expect that longer paths are more likely to include diversity antennas, which make these paths more robust against fading.

In short, paths with only a single modulation listed in ULS are likely to have more than sufficient margin to address the corner-case scenarios described by Comsearch and FWCC.[18] Although these paths do not have multiple modulations to choose from, even

[18] *See, e.g.*, Comsearch Comments at 14; FWCC Comments at 10; *see also* RLAN Group Comments at 20–21.

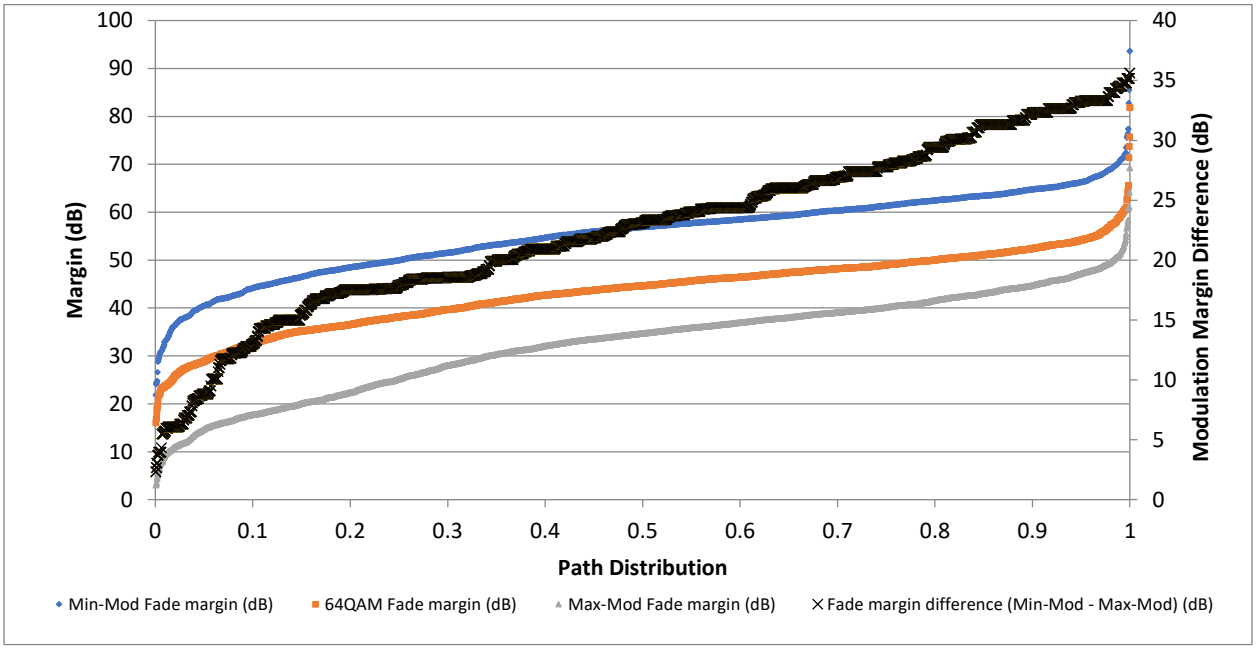
these paths would only experience outage if multiple different sources of interference simultaneously combined to exhaust their robust margins, and our previous I/N analysis and this margin demonstrates that such a scenario is extremely unlikely.

Multiple-Modulation FS Paths. Our dataset also included 3,304 paths that listed multiple modulations, indicating that they have adaptive modulation capabilities that allow the path to switch between modulations. Higher modulations offer the advantage of higher throughput, but they also operate with lower margins and are therefore more vulnerable to fade. Adaptive modulation systems allow FS services to trade off throughput while maintaining low error rates when the link margin degrades. Thus, for paths with multiple modulations, even in the unlikely event that multiple sources of interference occur simultaneously and exhaust the margin necessary for the highest order modulation, adaptive modulation is expected to fall back to a lower modulation until such interference diminished or subsided.

To assess whether these systems operate with excess margins, which would allow FS systems to achieve their required levels of availability even if the unlikely corner-case interference events over -6 dB I/N hypothesized by FWCC and Comsearch somehow occur, we reviewed the margin available for operations at the highest order modulation, 64 QAM (or the closest modulation to 64 QAM), and the lowest modulation. Those findings, shown in the distributions in Figure 5 below, demonstrate that in the vast majority of cases, there is excess margin above the minimum required for peak modulation (which will vary based on the distance and technical characteristics of each transmitter) and also a cushion so that even in the extremely unlikely event that multiple sources of interference occur simultaneously and exceed the margin for the highest modulation, the net effect could lead to temporarily reduced throughput rather than service outage. The black curve

demonstrates the absolute margin difference between the maximum modulation and the minimum modulation listed on a per link basis.

Figure 5: Distribution of FS Margin (in dB)
for Paths Operating at Minimum, 64 QAM, and Maximum Modulation



This distribution illustrates the significant difference—typically 20 to 26 dB—between the margin necessary to reach the highest order modulation and the lowest margin necessary to close the link. Adaptive modulation means that the lower levels of margin available at higher modulations do not, as some FS interests claim, necessarily make outages more common. While paths with multiple modulations options are capable of operating at higher order QAM, they will fall back to lower order QAM (and higher link margins) when experiencing margin loss, avoiding outage.

As with the single-modulation paths, we also looked at the average margin differences between the radio services as shown in Table 1 below. Here again, the paths performing critical public safety functions have the highest levels of margin. Notably, the average public safety path has more than the target 25 to 40 dB of path margin even when

operating at its highest modulation. These paths have on average almost 5 to 10 dB more margin than the already robust common carrier and business industrial services.

Table 1: Average FS Margin (in dB) for Paths Operating at Minimum, 64 QAM, and Maximum Modulation by Radio Service

	CF	MG	MW
Lowest Modulation	55.23 dB	53.46 dB	60.17 dB
64 QAM Modulation[19]	43.23 dB	41.77 dB	47.95 dB
Highest Modulation	29.95 dB	31.19 dB	39.6 dB

Additionally, for all of the services, Table 1 highlights that all sources of interference combined would need to cause the link margin to degrade by over 50 dB, even if we were assuming less efficient receiver implementations, in order for these paths to be broken.

Finally, we reviewed the impact of path distance on the margins for paths having multiple modulations listed in ULS as shown in Table 2 below. As with the paths with a single modulation, we found that shorter paths have significantly higher margin than longer paths. We also note that shorter paths typically are less susceptible to deep multipath fading conditions, so less margin is required even during the deepest fading conditions than for a longer path. Furthermore, we note that the longest paths are typically located outside of urban and suburban areas and, as such, are less likely to be surrounded by RLANs.

[19] *See supra* p. 15 (noting that closest modulation to 64 QAM was used when 64 QAM was not available).

Table 2: Average FS Margin (in dB) for Paths Operating at Minimum, 64 QAM, and Maximum Modulation by Path Distance

	0-10Km	>10Km-20Km	>20Km-30Km	>30Km-40Km	>40Km-50Km	>50Km
Lowest Modulation	64.46 dB	56.96 dB	56.12 dB	54.51 dB	52.22 dB	51.66 dB
64 QAM Modulation[20]	49.49 dB	44.59 dB	49.31 dB	42.74 dB	41.06 dB	40.75 dB
Highest Modulation	38.47 dB	32.62 dB	32.27 dB	32.34 dB	31.82 dB	32.93 dB

Finally, as noted when analyzing paths with a single modulation listed in ULS above, we expect that longer paths would be more likely to include space, frequency, and/or polarization diversity and other receiver techniques to reduce the effect of fade. The analysis presented above clearly shows that FS paths with multiple modulations have far larger margins than required to achieve their design target of 25 to 40 dB, and are more than capable of withstanding interference from the unlikely scenarios described by FWCC and Comsearch in this 6 GHz proceeding.[21]

Conclusions. The record in response to the NPRM demonstrates that RLANs can safely coexist with FS paths. This is because the vast majority of RLAN operations fall outside of the main beam of FS paths and are not positioned to even potentially degrade these operations.[22] Furthermore, even in a rare corner-case where an RLAN is positioned close enough to the main beam, *and* on an overlapping channel with the FS receiver, *and* positioned in a room facing the FS receiver—there are still likely to be multiple sources of attenuation, including significant building entry loss, that make harmful interference extremely unlikely.

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20 *Id.*

21 *See supra* note 18.

22 RLAN Group Comments at 20–21.

The margin analysis above adds yet another layer of belt-and-suspenders analysis. It demonstrates that even if, despite the rarity of the confluence of unlikely events described on the record, an RLAN somehow were to have energy levels above the -6 dB I/N criteria, this corner-case within a corner-case is unlikely to pose a real-world threat to FS operations. This is because the vast majority of paths are either operating with margins well beyond what is required, or they could fall back from a higher modulation to a lower modulation and still maintain their availability targets. The Commission can therefore even more confidently adopt the indoor low-power and very-low-power portable unlicensed operation rules as described in our comments, which will continue to maintain the reliability targets of FS paths. But it should not impose draconian technical limitations to protect FS paths from an extraordinarily unlikely confluence of circumstances that, even if it somehow occurred, would not cause paths to fail.

II. The Commission should reject calls to impose unnecessary restrictions that would cripple RLAN operations.

As detailed in the RLAN Group Comments and Broadcom's opening comments, the U-NII-5 band will play an essential role in the unlicensed ecosystem that the NPRM proposes for the 6 GHz band. Because of its mix of existing users, the U-NII-5 band provides a favorable environment for all three types of unlicensed operations outlined in the RLAN Group Comments: standard-power outdoor operations, low-power indoor operations, and very-low-power portable operations.[23]

Despite broad support for RLAN operations in this band, a small set of parties ask the Commission to impose severe and unnecessary restrictions on a substantial portion of the band. Specifically, certain companies that hope to sell C-V2X products in the adjacent

[23] *Id.* at 3.

5.9 GHz band propose prohibiting outdoor use of the bottom channel of U-NII-5. These companies support the NPRM's proposal to depart from the U-NII-3 rules protecting ITS in the 5.9 GHz band and instead impose a more severe OOBE limit of -27 dBm/MHz.[24] These restrictions would eliminate outdoor standard-power, AFC-controlled operations and very-low-power portable operations from a significant portion of the 6 GHz band.[25]

But the service that these companies propose to protect does not even exist. In fact, FCC rules *prohibit* C-V2X from using the 5.9 GHz band, and there are no commercially available C-V2X-equipped vehicles on the road. The Commission has already set an OOBE limit that protects the ITS services that are permitted in the 5.9 GHz band from unlicensed operations in U-NII-3, and C-V2X's proponent companies fail to provide any legitimate reason why the FCC should depart from that approach, especially to protect a service that does not exist and that the European Commission has just prohibited from operating in its ITS bands.[26] The Commission should therefore reject these concerns as speculative and unsupported.

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[24] The existing rules require that "[a]ll emissions shall be limited to a level of -27 dBm/MHz at 75 MHz or more above or below the band edge increasing linearly to 10 dBm/MHz at 25 MHz above or below the band edge, and from 25 MHz above or below the band edge increasing linearly to a level of 15.6 dBm/MHz at 5 MHz above or below the band edge, and from 5 MHz above or below the band edge increasing linearly to a level of 27 dBm/MHz at the band edge." 47 C.F.R. § 15.407(b)(4).

[25] Qualcomm Comments at 12–13; Comments of 5GAA at 6 ("5GAA Comments") (proposing that "all U-NII-5 operations using a channel with a center frequency below 5925 MHz + BW*3/2, where BW equals the bandwidth of the channel, must be limited to indoor-only operation"). Because there is not a practical way to tell whether a specific mobile hotspot is operating indoors or outdoors, an indoor-only restriction would effectively prohibit all very-low-power portable operations.

[26] Commission Delegated Regulation (EU) __ / __ of Mar. 13, 2019, Supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operational use of cooperative intelligent transport systems,

First, concerns about protecting C-V2X are, at this stage, pure speculation. Although numerous parties, including Broadcom, have been engaged in a long-running proceeding to determine the future of the 5.9 GHz band, the Commission has not yet reached a decision.[27] Until that process is complete, the *only* mobile service authorized to use the 5.9 GHz band is the Dedicated Short Range Communications ("DSRC") service. As the 5G Automotive Association's ("5GAA") recent petition to waive those rules recognizes, that means that C-V2X cannot today lawfully operate anywhere in the 5.9 GHz band.[28] If C-V2X does someday gain access to spectrum, it will be under as-yet undetermined technical rules, and in frequencies that have not been selected.

Consistent with its early stage of development, significant open questions remain about how (and whether) C-V2X will work.[29] Current research about C-V2X's performance is decidedly preliminary. C-V2X proponents support their claims about this technology with a single report, and 5GAA recently alerted the Commission that even that report is flawed—further evidence of the still uncertain nature of the technology.[30]

Moreover, C-V2X proponents have not provided the information needed to evaluate their potential interference claims. For example, C-V2X supporters have not provided

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C(2019)1789/F1, https://ec.europa.eu/transparency/regdoc/rep/3/2019/EN/C-2019-1789-F1-EN-MAIN-PART-1.PDF (not yet entered into force).

27 *See, e.g.*, Comments of Broadcom Inc. at 4, GN Docket No. 18-357 (filed Feb. 8, 2019).

28 *See* 5GAA Petition for Waiver at 2, GN Docket No. 18-357 (filed Nov. 21, 2018) ("5GAA Petition").

29 *See* Comments of Toyota Motor Corporation at 11–12, GN Docket No. 18-357 (filed Feb. 26, 2019).

30 Letter from Sean T. Conway, Counsel, 5G Automotive Association, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-357, at 1 (filed Feb. 22, 2019).

necessary analysis related to the channelization they are requesting. In this proceeding, 5GAA makes assertions about the minimum receiver sensitivity for 10-megahertz-channel operations—the only C-V2X channel size tested in their report.[31] But in their petition for waiver in the 5.9 GHz band, C-V2X proponents have asked the Commission to approve 20-megahertz-channel operations.[32] This inconsistency renders their claims, at best, confused. Nor have they provided complete information about what packet error rate C-V2X systems are designed to tolerate. 5GAA says packet errors may occur if undesired emissions exceed -100.4 dBm/MHz at the ITS receiver, but it offers no evidence about what level of packet loss C-V2X systems are designed to tolerate.[33] This could be central to the Commission's decision about OOBE levels. DSRC systems, for example, have been shown to perform their expected functions with packet error rates up to 50 percent.[34]

Furthermore, 5GAA fails to reveal basic information about its claims to allow the FCC or other parties to analyze their assertion that the Commission's proposed OOBE limit would allow unwanted signals in the ITS band at a signal strength of -85 dBm/MHz, assuming free-space path loss at a range of 3 meters.[35] For example, 5GAA does not state what RLAN power level or duty cycle it modeled. Understanding these basic assumptions is necessary to evaluate 5GAA's claims, because coincident traffic between RLAN and ITS safety operations is extremely unlikely. In a typical scenario where RLANs are operating on

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31 5GAA Comments at App. B - 5GAA Technical Response to the FCC 6 GHz NPRM.

32 *See* 5GAA Petition at 5.

33 5GAA Comments at App. B - 5GAA Technical Response to the FCC 6 GHz NPRM.

34 Comments of NCTA – The Internet & Television Association Regarding the Office of Engineering and Technology's Report on Phase I Testing of Prototype U-NII-4 Devices at 5, ET Docket No. 13-49 (filed Nov. 28, 2018).

35 5GAA Comments at 5.

a 160-megahertz channel at the bottom of the U-NII-5 band, we expect the RLAN duty cycle to be less than 1 percent, for a 5 Mbps video stream.[36] The DSRC basic safety message transmits for approximately 0.4 milliseconds 10 times per second, leading to a duty cycle of ~0.4 percent. We assume that a packet error rate of 20 percent for short packets carrying the same information every 100 milliseconds is acceptable and define the probability of an interference event as the probability of three collisions within a one-second interval. Determining the probability of three or more collisions occurring within ten consecutive ITS transmissions requires a binomial cumulative distribution function, which leads to 0.01 percent probability of interference. Importantly, this simultaneous transmission is only one of a series of factors (including signal-to-interference level and distance) that would be needed for an RLAN to even be in a position to cause harmful interference.

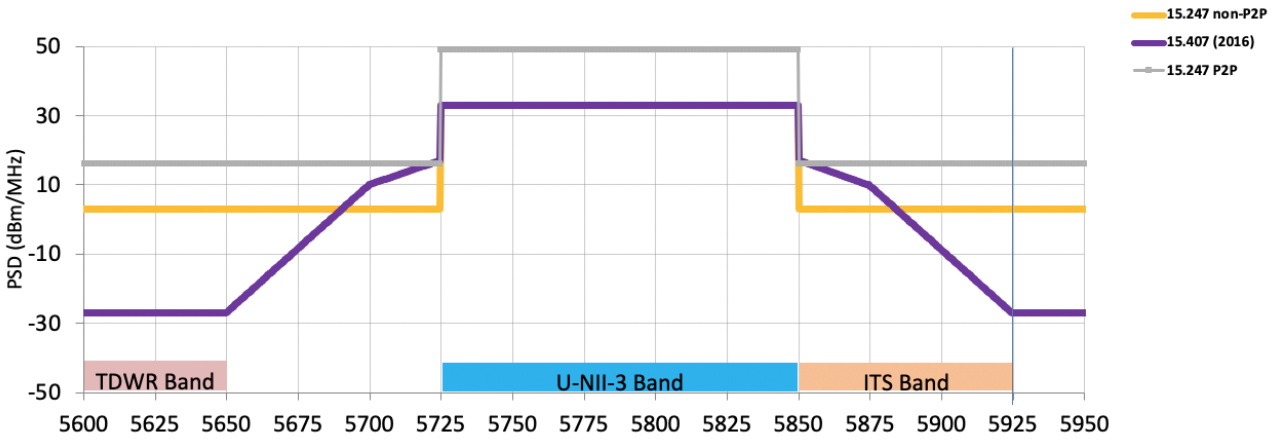
At a minimum, C-V2X proponents must provide (or, given that C-V2X remains in its early stages, develop) a full technical analysis of their proposed operations to support its claimed need for protection. As the Commission has recognized, other parties working toward a sharing solution for the 6 GHz band have engaged in detailed engineering analysis and discussions. The FCC should expect the same of C-V2X companies. Restricting the use of a proven technology like Wi-Fi—and thereby damaging the potential economic value of the 6 GHz band—to protect a technology that is not even permitted under today's rules risks wasting an important spectrum asset unnecessarily.

Second, the Commission has already adopted an OOBE limit that protects ITS operations in the 5.9 GHz band from unlicensed operations in the U-NII-3 band (5725 to

[36] This expectation is based on the use of MCS7 or greater at data rates of ~1 Gpbs or more.

5850 MHz).[37] That limit, which was adopted after significant engagement from interested parties, should also be applied to the upper edge of the 5.9 GHz band.

Figure 6: Existing U-NII-3 OOBE Limits



U-NII-3 is arguably the most successful unlicensed band in the 5 GHz spectrum. Hundreds of millions of devices are operating in U-NII-3 under the prior 15.247 OOBE rules, which allow point-to-point ("P2P") transmissions at +16 dBm/MHz throughout the entire ITS band and non-P2P transmissions at +3 dBm/MHz throughout the entire ITS band as can be derived from Figure 6 above.[38] Applying the current version of Section 15.407 of the FCC's rules, which was adopted in 2016, OOBE from U-NII-3 can permissibly reach:

- More than +15 dBm/MHz into the current ITS safety channel beginning at 5855 MHz;
- Approximately -12 dBm/MHz into 5905 MHz; and
- -27 dBm/MHz at 5925 MHz.

C-V2X proponents have not yet demonstrated harmful interference from the emissions levels already allowed into the ITS band, and automotive radio engineers already must design their systems with the assumption that the FCC's recently adopted U-NII-3

[37] 47 C.F.R. § 15.407(b)(4).

[38] *Id.*

OOBE rules will be in place—and there is a demonstrable benefit in extending the U-NII-3 rules to the U-NII-5 band to replicate U-NII-3's economic success.

Third, this proposed restriction on U-NII-5 operations raises serious questions about whether C-V2X operations are appropriate for the 5.9 GHz band at all. Existing FS users in the 5 GHz band—licensed incumbent operations that any new service like C-V2X would need to design around—would pose a significant interference challenge if C-V2X proponents' claims about OOBE interference risks are to be believed. Unlike unlicensed operations, which are expected to have a typical duty cycle of less than 1 percent for continuous data streams,[39] in our observations of various fixed services, we have found they typically broadcast energy even when there is no data transmission. As of March 2017, there were 3,702 FS paths registered in ULS that had approximately 30 MHz bandwidth, with the lower edge of the occupied channel at 5930 MHz (i.e., within 5 megahertz of the 5.9 GHz upper band edge).

The average EIRP of these 30-megahertz paths is 66.74 dBm, which means their average radiated PSD is approximately 52 dBm/MHz. Using the Part 101 emissions mask, adjusted for a 30 MHz FS, out-of-band emissions from these FS paths received at 5925 MHz are expected to be -62 dBr or -10 dBm/MHz.[40] If C-V2X is truly as vulnerable to unlicensed operations as indicated by its advocates' proposals, it is not clear how it can successfully operate even under current conditions. The Commission should consider whether these "eggshell" operations would be better positioned in a different spectrum band—or if they are even appropriate as safety technologies at all.

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[39] HPE Comments at 15.

[40] *See* 47 C.F.R. § 101.111.

Preliminary analysis suggests that concerns about interference from U-NII-5 are overblown. In research conducted as part of the proceeding on repurposing the U-NII-4 band, CableLabs and NCTA – The Internet & Television Association found that if unlicensed operations were allowed in the U-NII-4 band (where 80/160-megahertz RLAN channels could be directly adjacent to the ITS band-edge) there is only "0.002% probability that Wi-Fi operations would cause adjacent-channel DSRC packet error rates (PER) to reach 10%."[41] ITS should be at least as well protected from U-NII-5 operations, and likely more so given the proposed IEEE channelization for U-NII-5 with a 10-megahertz gap between the top of the 5.9 GHz band and the first channel of 6 GHz unlicensed operations.

Finally, unlicensed use of the entire U-NII-5 band is critical to the 6 GHz band's success. Adopting an unnecessary indoor-only restriction like the one envisioned by 5GAA would mean no 160-megahertz-channel outdoor operations in bands with a center point at or below 6165 MHz.[42] That eliminates one of the seven possible 160 MHz channels in the 6 GHz band.[43] Reducing the number of channels available for outdoor operations would harm the economic case for AFC and very-low-power deployment.

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41 Letter from Paul Margie, Counsel, NCTA – The Internet & Television Association, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 13-49, at Attach. (filed June 28, 2017).

42 5GAA Comments at App. B - 5GAA Technical Response to the FCC 6 GHz NPRM.

43 The anticipated channelization for U-NII-5 has a bottom band-edge at 5935 GHz, so the second-adjacent 160-megahertz channel to U-NII-4 is centered at 6175 MHz.

III. The Commission should affirm its proposal to open the U-NII-7 band for unlicensed use and reject calls to reserve the band for a single type of unlicensed technology.

U-NII-7 is ideal for all three proposed types of unlicensed operations: standard-power, low-power indoor, and very-low-power APs and associated client devices.[44] In addition to the outdoor operations the Commission has proposed for U-NII-7, Broadcom has demonstrated that U-NII-7 can safely host indoor low-power operations and very-low-power portable operations without causing degradation to incumbent operations.[45] Modifying the Commission's proposal to allow a wider array of unlicensed operations is critical to U-NII-7's success because three of the 6 GHz band's seven 160-megahertz channels are wholly or partially contained in that sub-band.[46] To ensure that this valuable spectrum is intensively used, the Commission should adopt technology-neutral rules that give operators and equipment makers flexibility to implement different kinds of solutions—as long as they provide adequate protection to incumbent services.

But one company asks the FCC to violate its principles of technology neutrality and impose unprecedented restrictions on an unlicensed band in order to reserve U-NII-7 for a single class of unlicensed technologies, which happen to be the technologies it plans to sell. Specifically, this company asks the FCC to reserve the U-NII-7 band for unlicensed devices that use "synchronized operations."[47] Make no mistake—this is simply a proposal to use FCC regulations as a set aside for a specific unlicensed technology and would block the band from Wi-Fi device operation.

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44 RLAN Group Comments at 3.

45 Broadcom Comments at 5–16, 27–34.

46 *Id.* at 27 fig.13.

47 Qualcomm Comments at 18–22.

The Commission should reject this proposal. It threatens the overall success of the band without offering any legitimate benefit. Imposing this burdensome regulation would not provide near-term public interest benefits sufficient to justify the enormous loss of spectrum value it would cause. Instead of imposing rules to effectively mandate a single favored class of unlicensed devices, the Commission should follow its time-tested practices. It should set technology-neutral rules for unlicensed bands and allow standards bodies to work on co-existence solutions. If a particular technology has promise, industry will debate its inclusion into next-generation technologies and incorporate it where appropriate. To our knowledge, such a rigorous debate about the synchronization methods proposed for U-NII-7 has not yet even begun in any standards body. The Commission should not short-circuit their work with overly prescriptive rules.

CONCLUSION

The need for more unlicensed spectrum grows every day. As detailed in comments filed by Broadcom and in the RLAN Group Comments, the Commission's forward-looking proposal to open the 6 GHz band to unlicensed operations is critical to the future growth of Wi-Fi and other unlicensed services. For the reasons described above, the Commission should recognize that unlicensed operations pose no real-world danger to FS operations and reject calls for unnecessary technical regulations. The Commission should adopt the NPRM's proposals, with the modifications Broadcom has suggested, and quickly bring the 6 GHz band into more efficient use.

Respectfully submitted,

Christopher Szymanski
Director, Product Marketing and Government Affairs

Vinko Erceg
Fellow, Systems Engineering

Thomas Derham
Principal Engineer, Systems Engineering

BROADCOM INC.
15191 Alton Parkway
Irvine, CA 92618

March 18, 2019